From the results of these experiments it may be stated that—

1. The initial decomposition of ethylene by heat is very rapid, and requires but a short flow through a heated containing vessel, such primary decomposition, however, being but slowly completed, owing to secondary reactions, which tend to re-form ethylene.
2. Dilution has but little effect in retarding the decomposition of ethylene, unless it be very large.
3. Increase in rate of flow diminishes the amount of decomposition when the heated area is small, but rapidly diminishes in effect as the length of flow through a heated area increases.
4. The decomposition of ethylene is chiefly caused by radiant heat, the effect of which is very great as compared with the decomposition due to contact with heated surfaces.

I desire to acknowledge the valuable aid given me by Mr. F. B. Grundy in this investigation.

III. "On the Measurement of Pressures by the Crusher-Gauge." By W. Kellner and W. H. Deering. Communicated by Dr. W. Anderson, F.R.S. Received January 21, 1895.

The object of the experiments, the results of which are given in this paper, was to compare the indication of pressure (produced by the firing in a closed vessel of a gunpowder) by the crusher-gauge with a simultaneous estimation of the same pressure by another and simple method. This latter consisted in ascertaining the weight which was equal to the maximum pressure of the gases of the fired cordite (the smokeless gunpowder used in these experiments) acting on a valve closing gas-tight an opening in the explosion-vessel of area small enough to allow of the use of weights of manageable amount, not so small a fraction of the unit of surface (1 sq. in.) as to have to use a very large multiplier. Within the explosion-vessel, on the top of which were the valve and weights, was placed the crusher-gauge, the firing of the charge of cordite giving the two indications of pressure. In the "weights" method, a series of short steps was taken, weights in excess of that required being placed on the valve, the cordite fired, and it being observed whether the gases of explosion were blown out of, or kept in, the vessel. The amount of compression of the copper-crusher was then measured, and the corresponding pressure ascertained from the existing tables. In the next experiment the weights were lightened, and so on, until the gas blew out of the vessel, the mean of the pressure at the blow-out point and of that in the last experiment in

which the gas was kept in the vessel being taken as the pressure required. A pressure by copper-crusher was taken in each experiment made, and the mean of the series taken; the compression of the crusher was the same in the experiments of a series, whether the gases blew out of, or were kept in, the explosion-vessel, the weights apparently not being raised before the compression of the copper had come to an end.

It may be not superfluous to mention that the copper-crusher is a small cylinder of copper, before compression 0·5 in. long and 0·326 in. in diameter, one end of which rests on the base of a steel case in which it is contained, the other end being in contact with one end of a movable piston of 0·461 in. diameter ($\frac{1}{6}$ sq. in. section), on the other end of which the gases exert their pressure; suitable provision is made to prevent entrance of gas to the gauge-case, and to hold the copper-crusher in position while allowing room for its widening in the middle by compression. The coppers are used previously pressed to about a ton short of the pressure to be measured.

Rumford, in 1797, used a "weights" method to ascertain the relation existing between the pressure produced by a fired gunpowder and the density of the charge $\left(\frac{\text{weight of gunpowder}}{\text{volume of explosion-vessel}}\right)$. He used charges of gunpowder from 1 to 18 grains in weight, density of charge varied from 0·04 to 0·76, and the pressures measured were consequently very high; the weight just lifted by the pressure of the powder gases was found by a series of trials.

Bunsen also ('Gasometrische Methoden') used the same method, of course very much altered in details, to ascertain the pressures produced by the combustion of some gases in oxygen; the gaseous mixtures were at 1 atmos. pressure, the increase of pressure produced on firing the mixtures was at highest about 10 atmos. (about $\frac{1}{15}$ ton per sq. in.).

In our experiments, the gases of the fired explosive served only as a medium for comparing the two methods of estimating pressure, so that the question of any lowering of temperature by heating of the explosion-vessel did not come into consideration.

This direct experimental method of checking the crusher-gauge indications is preferable to calculation of pressure from the ascertained amounts of permanent gases, water, and quantity of heat produced at the pressures in question, because the calculation requires knowledge of the specific heat of the gases of combustion at (in the case of cordite) about 3000° C., and although there is valuable information on the subject, it is scarcely sufficiently accurate for this application of it. Again, the compression of the copper-crusher measures the maximum pressure of the gases, when (at the temperature mentioned) some dissociation of carbonic acid would occur (or

rather some oxygen and carbonic oxide would co-exist), while the quantity of heat is measured in the cooled-down gases when all oxygen and carbonic oxide have combined; here, also, it would not be practicable with existing information to make an accurate allowance for difference of heat-quantity under the conditions of the experiment. Further, in calculating the pressure of the gases from their calculated temperature, it is assumed that their coefficients of expansion which were determined for 0° to 100° C. are valid at 3000° C. (At 0°, air is only about 190° above, and water is 100° below, its boiling temperature.)

If temperature were independently known, the drawbacks just mentioned in the use of the coefficient of expansion, and of the volume of gases, still apply to the calculation of pressure; and, conversely, to the frequent case of calculating temperature from ascertained pressure.

The steel explosion-vessels used in our experiments were of about 120 c.c. capacity; they were closed by screw stoppers of about 4 ins. total length (the screw portion about $1\frac{1}{2}$ ins. long), the end of which was screwed down to gas-tight contact with the circular seating forming the mouth of the explosion-chamber. The stoppers had a square head at starting 2 ins. long; the whole stopper was perforated axially with a cylindrical hole $\frac{1}{4}$ in. in diameter. The mouth of the hole in the stopper was closed by a steel ball of $\frac{1}{2}$ in. in diameter (which formed the valve), a ball such as is used for ball-bearings; on the ball a 1-in. thick iron plate, about 15 ins. by 15 ins., was placed (the centre of the plate being perforated by a cylindrical hole $\frac{1}{4}$ in. in diameter, resting on the top of the ball), and on the plate the weights. The latter consisted of lead cylinders, weighing about 5 cwt. and 8 cwt. respectively (diameters 14 ins. and 12 ins.); of the former, at the most three (placed on top of each other), and of the latter, two, were used. The weight was made up with half-hundredweights and smaller weights placed on the top of the upper lead-cylinder; all the weights, lead-cylinders, iron plate, and iron rod, were weighed at the beginning and end of the experiments by standard weights.

The explosion-vessels had externally a collar and a hexagonal portion fitting into a hexagonal hole in an iron plate, which was screwed to a balk of timber, held in place by weights; this held the explosion-vessel while the screw-stopper was hammered down, and formed the base of the apparatus. The lead cylinders had an axial cylindrical hole to their centre; in the hole of the top cylinder an iron rod (about 1 in. diameter, 4 ft. long) was placed, the upper end of the rod passing loosely through a hole in a cross-beam kept in position by iron uprights on either side of the base of the apparatus. The weights were carefully balanced, so that pressure of iron rod against cross-beam was reduced to an inconsiderable amount. The lead

cylinders were readily placed in position on the iron plate (held horizontal by wedges until cylinders and weights were in position) by means of a movable crane.

The firing of the cordite charge was effected by means of a wire-bridge heated to redness by an electric current; on the centre of the wire-bridge a small piece of the cordite was firmly hung. One end of the wire-bridge was soldered to the end of a steel pin forming part of the stopper, the other end was soldered to the end of a steel wire of $\frac{1}{20}$ in. diameter cemented by a suitable resinous cement in a hole of $\frac{1}{16}$ in. diameter passing through the length of the stopper. By reducing the area of the insulated wire to this small amount, the cement held the wire gas-tight against the highest pressure (16 tons per sq. in.) employed. In the 14-ton and 16-ton experiments, the stopper was cooled by a little ice placed on its upper surface, to prevent softening of the cement.

The area of the mouth of the hole in the stopper was measured by means of a microscope with a cross-wire, the microscope moving horizontally on a graduated scale and carrying a vernier. The pressure of the weights on the steel ball and stopper slightly bevels the mouth of the latter; at the commencement of a series of experiments, weights to about the maximum amount to be used were placed on the steel ball, and four diameters of the inner and lower circle of the bevelled contact-ring were then measured with the microscope-vernier. The area was re-measured in the course of several of the series, and found to be unchanged.

One hundred and twenty-six experiments in all were made; a few of these were lost by the weight required having been under-estimated and the gases blowing out on the first experiment of a series being made. A few of them also were lost by the blowing out of the insulated wire, or by other causes. The remainder form twenty-seven series (a series consisting of at least two experiments: in one of which the gases were kept in, and were blown out in the following one), the results (viz., the mean of the last two experiments) of which are given below. Eight series consisted of two experiments, two of three, six of four, three of five, six of six, one of seven, one of eight.

The gases were either wholly kept in, or wholly blown out of, the explosion vessel. In the former case there was no report and no damage to the steel ball, which could be used for all the experiments of a series; in the latter case there was a loud report, and the mouth of the hole in the stopper was slightly injured (the steel being melted and blown away by the gases), and a ring melted in the steel ball. A new steel ball was, of course, used for each series of experiments. For the experiments at the lower pressures of 5 and 6 tons, the hole in the stopper was (after damage by the blown-out gases) enlarged at the top (to a depth of $\frac{1}{8}$ in.) to 0·35 in., and subsequently to 0·40 in.

diameter, thus affording a check by varying area. For the 13- and 16-ton experiments, the 0·25-in. hole only was used, as the weights required for the larger holes would have been unmanageable with the means available at the time; in this case, when damage to the mouth of the hole in the stopper occurred by the blowing out of the gases, the head of the stopper was only planed down.

The amounts by which the weights were lightened in the last (and usually in each) experiment of a series was the following:—

	5 tons.	6 tons.	13 tons.	16 tons. 8 series.	
	1 series.	4 series.	2 series.	5 series.	3 series.
0·25-inch hole.	22 lbs. = 0·2 ton	14 lbs. = 0·13 ton	28 lbs. = 0·26 ton	28 lbs. = 0·26 ton	56 lbs. = 0·52 ton per sq. in.

	5 tons.	6 tons. 6 series.		
	1 series.	1 series.	1 series.	4 series.
0·35-inch hole.	56 lbs. = 0·26 ton	56 lbs. = 0·27 ton	28 lbs. = 0·13 ton	14 lbs. = 0·06 ton per sq. in.

	5 tons.	6 tons.
	1 series.	4 series.
0·40-inch hole.	56 lbs. = 0·2 ton	28 lbs. = 0·1 ton per sq. inch.

The weight-differences are, of course, calculated into tons per square inch on the *measured* areas of the holes, the diameters f which differed slightly from 0·25 in., &c. As mentioned above, half the weight-difference (the mean of the last two experiments of a series) is taken for the end result.

The following were the results obtained :—

Hole 0·25 inch diameter.

						Mean of the 4.	
By weights	5·7	7·0	7·0	6·9	6·8	6·9	Tons per sq. in.
By crusher	5·1	6·2	6·5	6·6	6·0	6·3	
Weights *minus* crusher	0·6	0·8	0·5	0·3	0·8	0·6	

Hole 0·35 inch diameter.

								Mean of the 6.	
By weights	5·9	7·0	7·0	6·8	6·9	7·1	7·2	7·0	Tons per sq. in.
By crusher	5·2	6·3	6·3	6·4	6·4	6·6	6·2	6·4	
Weights *minus* crusher	0·7	0·7	0·7	0·4	0·5	0·5	1·0	0·6	

Hole 0·40 inch diameter.

						Mean of the 4.	
By weights	5·9	6·8	7·0	7·3	7·1	7·0	Tons per sq. in.
By crusher	5·2	6·4	6·4	6·3	6·4	6·4	
Weights *minus* crusher	0·7	0·4	0·6	1·0	0·7	0·6	

Hole 0·25 inch diameter.

			Mean of the 2.									Mean of the 8.	
By weights	14·7	14·4	14·6	18·5	18·9	18·1	18·8	17·9	18·2	18·7	18·2	18·4	Tons per sq. in.
By crusher	13·2	13·0	13·1	15·7	15·9	15·6	15·8	15·9	15·9	15·8	15·6	15·8	
Weights *minus* crusher	1·5	1·4	1·5	2·8	3·0	2·5	3·0	2·0	2·3	2·9	2·6	2·6	

The pressure by weights was invariably higher than by crusher; at 5 tons (by crusher) the difference was about 11 per cent., at 6 tons about 9 per cent., at 13 tons about 11 per cent., at 16 tons about 16 per cent. At 5, 6, and 13 tons there is usually (but not always) less difference between the individual pressures by crusher given above than between the weights pressures; at 16 tons there is decidedly greater regularity in the crusher results than in those by weights; the crusher pressures are, however, the means of series, which favours them somewhat.

Presents, March 7, 1895.

Transactions.

London:—British Astronomical Association. Journal. Vol. V. No. 4. 8vo. *London* 1895. The Association.

Geologists' Association. Proceedings. Vol. XIV. Part 1. 8vo. *London* 1895. The Association.

Iron and Steel Institute. Journal. 1894. No. 2. 8vo. *London* 1895; Brief Index of the Papers contained in the Journal. 1869–94. 8vo. *London* 1895. The Institute.

Odontological Society. Transactions. Vol. XXVII. No. 3. 8vo. *London* 1895. The Society.

Royal College of Physicians. List of the Fellows, Members, Extra-Licentiates, and Licentiates. 1895. 8vo. *London.* The College.

Royal Meteorological Society. Quarterly Journal. Vol. XXI. No. 93. 8vo. *London* 1895; Meteorological Record. Vol. XIV. No. 54. 8vo. *London.* The Society.

Royal Microscopical Society. Journal. 1895. Part 1. 8vo. *London.* The Society.

Newcastle-on-Tyne:—North of England Institute of Mining and Mechanical Engineers. Transactions. Vol. XLIV. Part 2. 8vo. *Newcastle-on-Tyne* 1895. The Institute.

Penzance:—Royal Geological Society of Cornwall. Transactions. Vol. XI. Part 9. 8vo. *Penzance* 1895. The Society.

Santiago:—Sociedad Nacional de Mineria. Boletin. Año XI. No. 73. 4to. *Santiago de Chile* 1894. The Society.

Stockholm:—Kongl. Vetenskaps Akademie. Öfversigt. Årg. LI. No. 10. 8vo. *Stockholm* 1894. The Academy.

Toulouse:—Académie des Sciences, Inscriptions, et Belles-Lettres. Mémoires. Série 9. Tome VI. 8vo. *Toulouse* 1894. The Academy.

Faculté des Sciences. Annales. Tome IX. Fasc. 1. 4to. *Paris* 1895. The Faculty.